A comparison of instrument-centering ability within the root canal for three contemporary instrumentation techniques

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Abstract

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Aim To study and compare Great Taper (GT) hand files using a reversed balanced force technique, nickel–titanium (NiTi)flex files with a balanced force technique and stainless steel (SS) K-type files using a step-back technique.

Methodology Forty-eight extracted mandibular premolar teeth with single root canals having curvatures between 15 and 45° were prepared using a modified Bramante model and randomly divided into three groups. The teeth were cross-sectioned at 2, 6 and 10 mm from the working length. Preoperative images of canals at three levels were captured at 20× magnification using a stereomicroscope. Canals in each group were, respectively, prepared to an apical size .10 GT file with 0.2 mm tip diameter, size 30 NiTiflex file and size 30 SS K-file. The GT file was used in a reversed balanced force technique, the NiTiflex file was used in a balanced force technique, and the SS K-file was used in a step-back technique. Postoperative canals were imaged under the conditions same as those for the preoperative canals. The postoperative images were superimposed over the preoperative images using software PHOTOSHOP 6.0. The ability to maintain the instrument in the central axis of the canal and the deviation from the central canal axis were determined and compared by statistical analysis, along with the assessment of the amount of dentine removed.

Results At apical level, the centering ratio, the distance of transportation and the dentine removed in GT and NiTiflex groups were significantly less than those in SS group ($P < 0.01$), but no statistical differences were found between the two NiTi groups. At other levels, there were no substantial differences amongst the groups.

Conclusions Compared with SS K-files, GT hand files and NiTiflex files remain better centered and produce significantly less transportation in curved canals.

Keywords: centering ratio, curved canal, root canal preparation, transportation.

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Introduction

Root canal cleaning and shaping play a crucial role in the success of endodontic treatment. The purpose of shaping during instrumentation is to create a continuously tapering conical canal configuration suitable for obturation (Schilder & Yee 1984), whilst the cleaning is primarily accomplished with the use of irrigants. Shaping is easily accomplished in straight canals, but in curved canals, there is a tendency to transport the canal away from its original axis. Enlargement of a curved root canal with some traditional stainless steel (SS) files often results in unwanted alterations in the canal shape, such as transportation, ledge formation and sometimes even perforation (Al-Omari *et al.* 1992). Whilst nickel–titanium (NiTi) instruments possess high flexibility and torsional

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resistance, instrumentation with them can effectively decrease aberrations in canals (Bryant *et al.* 1998).

Great Taper (GT) files (Dentsply Maillefer, Ballaigues, Switzerland; Dentsply Tulsa Dental, Tulsa, USA) are a generation of non-ISO NiTi endodontic instruments that are available in hand and rotary design (Buchanan 2000). Required to create centered, continuously tapered preparations in a wide range of root canal forms, both types of GT instruments hold a common tip diameter of 0.2 mm, common maximum flute diameter (MFD) of 1.0 mm and variably pitched flute pattern with four basic tapers, .06, .08, .10 and .12 mm mm^{-1}. For GT hand files, the design consists of reverse-cut triangular flutes. Previous studies reported that transportation and weakened tooth structure occurred less in canals shaped with GT rotary files than with conventional SS Flexofiles (Gluskin *et al.* 2001). However, the centering ability in curved root canals either for GT rotary instruments or for hand files has not been examined extensively. The aim of the current study was to evaluate GT hand files for their ability to remain centered in curved root canals, the distance of transportation and the amount of dentine removed, and compare these findings with traditional ISO NiTiflex files (Dentsply Maillefer, Ballaigues, Switzerland) and SS K-type files.

Materials and methods

Extracted human mandibular premolar teeth with mature apices and no noticeable defects or abnormal root morphology were stored in 10% formalin. Standard access openings were made into the pulp chambers, and the cusps were flatted to provide a reliable reference for length measurement. In order to reduce the variation for the apical diameter of the canals before instrumentation, the teeth whose apical foramen could be penetrated with a size 20 Flexofile (Dentsply Maillefer, Ballaigues, Switzerland), without resistance, were excluded to make the apical diameter of specimens probably less than 0.2 mm. The working length was established 1 mm short of the canal length that was determined by inserting a size 15 Flexofile into the canal until it was visible at the apical foramen and the file tip flush with the root surface. With the file in canal, radiographs were then taken in the mesial–distal (M-D) and buccal–lingual (B-L) direction. The radiographs for teeth with single root canal and unidirectional curve were selected for canal curvature measurement. They were projected individually by a vertically mounted slide projector onto a piece of A4 white paper that was secured to a lab bench. The projected file and root canal outlines were traced with a pencil. The angles of curvature were determined using the method described by Schneider (1971). The larger curvature (M-D or B-L) was recorded as the canal curvature. Forty-eight extracted mandibular premolars with single root canals were finally included in the study conforming to the following criteria: (i) the diameter of the apical foramen was less than 0.2 mm; (ii) the canal length exceeded 18 mm from the occlusal reference point; and (iii) the canal curvature was between 15 and 45°.

All teeth were prepared using a modification of the model according to Bramante (Bramante *et al.* 1987). First, three red lines, perpendicular to the root canal, were drawn directly onto the root surfaces at 2, 6 and 10 mm short of the working length. At the same positions to the red lines, three grooves that did not reach the canal were made into the tooth structure with a 0.2-mm thick carborundum disc mounted on a milling machine and perpendicular to the root surfaces. Red wax was placed into the three grooves and flush with the root surfaces to guide the sectioning of each specimen. Apical foramina were sealed with wax to prevent the unset resin in the following step from penetrating into the apical portions of the canals. Each tooth was individually embedded in clear acrylic resin (Nissin, Tokyo, Japan) that was poured into a removable muffle. The muffle was made of two halves that could be fastened together or released with the help of locking attachment. At least two horizontal and vertical grooves, respectively, had been made on the inner surface of each muffle half to ensure the exact repositioning of the specimen embedded in the resin. After the resin had set, the muffles were opened and the resin blocks removed. Along the three grooves marked with red wax on the root surfaces, three grooves were made into the resin blocks with the carborundum disc until it reached the red wax. Next the blocks were sectioned at the grooves using a chisel and gentle tapping. Some blue wax was placed into the coronal ends of each cross-sectional canal in the sections to define all preinstrumented canal outlines. Impressions for the bottom of each section were made to act as a mould to hold the sections in a convenient and reproducible position for pre- and postinstrumentation photography. The preoperative cross-sectional images of coronal cut surfaces in each section were then magnified 20 times and captured by a stereomicroscope and a camera. A millimetre scale was also photographed under the same conditions to calibrate the subsequent measurement. The blue wax was then removed, and the sections were reassembled in the muffles. The 48 specimens were grouped in ascending order of canal curvature. In order to achieve equal distribution of canal

curvature, a blocked randomization was used to assign the teeth in the muffles into three groups to give a total of 16 teeth in each. The root canals in each group were prepared by one operator with one of the instrumentation techniques as follows. Each set of instruments was used in no more than five canals in all groups.

GT group

Specimens in this group were instrumented with GT hand files (Dentsply Tulsa Dental). As the flutes for these files thread to the left instead of the right as with standard K-files, a reversed balanced-force technique was recommended (Blum *et al.* 2001). The procedures were as follows: a .10 GT hand file with a .10 taper and 0.2 mm tip diameter was inserted into the canal until resistance was met and then rotated 90–180° counter-clockwise to engage dentine. Afterward, the file was turned clockwise 360–720° until it failed to cut dentine during rotation. Next the file was turned 90–180° counter-clockwise to load the flutes and then removed from the canal. After cleaning debris in flutes, the root canal was irrigated with 2 mL of 2% sodium hypochlorite and the file was reinserted in the canal. The steps described above were repeated until the final preparation was finished when the .10 GT hand file reached the working length.

NT group

.02 taper NiTiflex files (Dentsply Maillefer) and a balanced force technique were used to prepare the 16 root canals in this group. A size 20 NiTiflex file was introduced into the root canal until binding was obtained by using a 90–180° clockwise rotation. The file was then turned in a counter-clockwise rotation 180–360° with inward pressure to engage dentine. Afterward, the next step was to pull outward the file with 90–180° clockwise rotation to load the flutes with debris. After cleaning the flutes, the root canal was irrigated with 2 mL of 2% sodium hypochlorite, the file was reinserted into the canal and the motion above was repeated until the instrument reached the working length. Each sequentially larger file was worked in a similar fashion until the apical preparation was completed with a size 30 NiTiflex file.

SS group

Instrumentation was performed with .02 taper SS K-files (Dentsply Maillefer) using a step-back technique. A size 20 file was placed to length, and a combination of a filing and a reciprocal reaming action was used until it fitted loosely in the canal and reached the working length. This procedure was repeated with successively larger files until the apical portion of the canal was prepared to a size 30 file. Irrigation with 2 mL of 2% sodium hypochlorite was used after each file in each canal.

In the NT and SS groups, successively larger NiTiflex and SS K-type files were inserted 1.0 mm short of the previous file until a size 60 file was placed to a point 6 mm from the terminus. Then, a no. 2 Gates–Glidden bur (Dentsply Maillefer) was advanced to that point in the canal. The step-back flaring of the remainder of the canal was performed using increasingly larger Gates–Glidden burs from no. 2 to no. 4 at 2-mm steps short of each other. Recapitulation to the working length with a size 30 file and irrigation with 2 mL of 2% sodium hypochlorite after each file were necessary throughout the step-back procedures for each canal.

When preparation in all canals was finished, the incidence of separated instruments and loss of working length were recorded for each group. The tooth blocks were disassembled, and red wax was inserted into the coronal ends of the canals in the sections. The coronal cut surface of postoperative canal in each section was imaged under the conditions same as those for the preoperative samples. During the course of experiment, specimens and their sections were stored in 100% humidity between procedures throughout the operating period.

All photographs were scanned into the computer and processed by an examiner who was blinded with respect of all to the experimental groups. Using PHOTOSHOP 6.0 (Adobe Systems Incorporated, Seattle, USA), the postoperative canal images with 50% opacity were superimposed over the preoperative images by superposing the three dots (three green dots in Figs 1–3) selected in the pre- and postinstrumented images at the same positions. The ability of instruments to remain centered in the canal was determined by calculating a centering ratio. Observing and measuring the original canals position in the canals instrumented, the centering ratio was calculated by the formula $X1 - X2/Y$ (X1 represents the maximum extent of canal movement in one direction, and X2 is the movement in the opposite direction; Y is the diameter of the final canal preparation) (Calhoun & Montgomery 1988). The distance of transportation was determined by measuring the greatest length between the edge of each instrumented canal and the corresponding edge of the uninstrumented canal. The amount of dentine removed was scored with the differences in cross-sectional canal area of sections

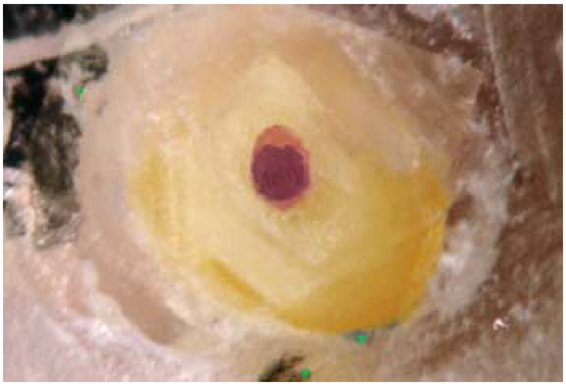

Figure 1 The superimposed image of tooth no. 22 at apical level in GT group (×20). Curvature: 26.2°. CR (centering ratio): 0.1628. X1 (the maximum canal movements in one direction): 0.13 mm. Removed dentine: 0.0819 mm^2. The three green dots are the superimposed dots at the same position in pre- and post-instrumentation images.

Figure 3 The superimposed image of tooth no. 32 at apical level in NT group (×20). Curvature: 17.4°. CR:0.1188. X1: 0.15 mm. Removed dentine: 0.1260 mm^2. The three green dots are the superimposed dots at the same position in pre- and post-instrumentation images.

between pre- and postinstrumentation. Each specimen was examined, and scores at the three levels for the centering ratio were compared; the distance of transportation was determined, and the amount of dentine removed was assessed. These data were analysed statistically with a one-way ANOVA and the Student-Newman-Keuls test to determine differences amongst the groups. The level of significance was $P < 0.05$.

Results

For the 48 single root canal teeth, the mean curvature for each group was 25.31 ± 6.97, 25.94 ± 7.37 and $26.54 \pm 7.31°$, respectively; there were no significant

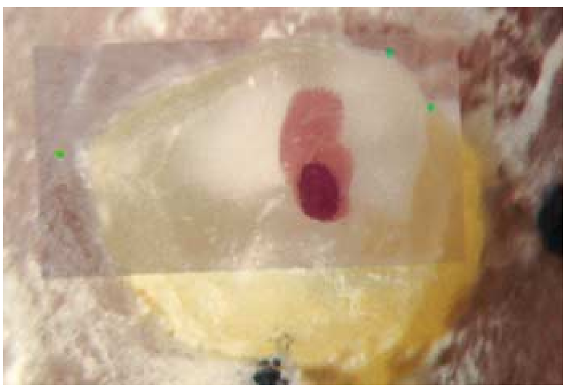

Figure 2 The superimposed image of tooth no. 25 at apical level in SS group (×20). Curvature: 27.9°. CR:0.5529. X1: 0.47 mm. Removed dentine: 0.2936 mm^2. The three green dots are the superimposed dots at the same position in pre- and post-instrumentation images.

differences amongst them as shown by *F*-test. During instrumentation, only one instrument fracture, a 0.5 mm length of the tip of a size 30 NiTiflex file, was fractured in the apical portion 0.5 mm short of the working length in a canal with a curvature of 42.1°. However, the length of the file segment in the apical portion of the canal had no influence on the apical instrumentation and step-back preparation. In other specimens, there was no occurrence for apical blockage or loss of working length. Table 1 shows the mean centering ratio 2 (apical), 6 (middle) and 10 mm (coronal) short of the working length in three groups. Table 2 lists the mean distance of transportation at three levels in each group. The mean amount of dentine removed for three cut surfaces is presented in Table 3. At the apical level, the centering ratio, the dentine removed and the distance of transportation in GT and NT groups were significantly less than those in SS group ($P < 0.01$), but no statistical difference was found between the two NiTi groups. At other two levels, there was no substantial difference amongst groups. Figures 1–3 show the superimposed images of pre- and postoperative canals at the apical level.

Table 1 Mean centering ratio for three cut surfaces in each group (mean ± SD)

Group	Apical	Middle	Coronal
GT	0.1563 ± 0.1050*	0.1497 ± 0.1204	0.1130 ± 0.0624
SS	0.3545 ± 0.1309*	0.1642 ± 0.0965	0.1440 ± 0.0816
NT	0.2116 ± 0.1151*	0.1223 ± 0.0668	0.1224 ± 0.0302

*Shows a significant difference amongst groups ($P < 0.01$, SS > GT, NT).

Table 2 Mean distance of transportation (mm) at three levels in each group (mean ± SD)

Group	Apical	Middle	Coronal
GT	0.1594 ± 0.0644*	0.2081 ± 0.0868	0.2263 ± 0.0828
SS	0.2906 ± 0.1248*	0.1750 ± 0.0794	0.2044 ± 0.1007
NT	0.1719 ± 0.1124*	0.1419 ± 0.0723	0.1694 ± 0.0809

*Shows a significant difference amongst groups ($P < 0.01$, SS > GT, NT).

Table 3 Mean increase of root canal cross-sectional areas (mm^2) at three cut surfaces in each group (mean ± SD)

Group	Apical	Middle	Coronal
GT	0.1422 ± 0.0568*	0.3453 ± 0.1019	0.5743 ± 0.1421
SS	0.2293 ± 0.1456*	0.3307 ± 0.1312	0.5761 ± 0.1730
NT	0.1231 ± 0.0661*	0.2601 ± 0.0982	0.4745 ± 0.2559

*Shows a significant difference amongst groups ($P < 0.01$, SS > GT, NT).

Discussion

As Bramante introduced a muffle system to compare and study the new instruments and techniques, the method has been used widely (Glosson *et al.* 1995, Samyn *et al.* 1996, Bertrand *et al.* 2001). Obtaining identical pre- and postinstrumentation images of the root canal is possible, which then facilitates evaluation for transportation in prepared canals. However, because of the thickness and lateral movement of the band saw, some loss of root material occurs. Furthermore, some oblique-sectioned surfaces in curved canals could act as ledges that hinder the file from advancing to the working length (Portenier *et al.* 1998, Deplazes *et al.* 2001). In the present study, loss of root material did not restrain instrumentation from being performed completely in all teeth, which could be because of the sectioning method. In the experiment, the roots of extracted teeth were sectioned with a chisel, which possibly resulted in less root material loss than that for the method with the low-speed saw.

In this study, some efforts were made to reduce variations amongst the specimens. First, the teeth with multicurved root or any abnormal root configuration were excluded to facilitate the curvature measurement and make the measured curvature more credible. The teeth for which the size 20 Flexofile could go through the foramen with no resistance were also excluded in the experiment, which controlled the apical diameter to less than 0.2 mm before instrumentation. In addition, by a sampling method of blocked randomization, the curvature was evenly assigned into the three groups. The master apical file selected for each group was .10 GT hand file with 0.2 mm tip diameter, size 30 SS K-file and size 30 NiTiflex file, respectively. Under the conditions of each specific instrumentation technique, the diameter of shaped canals 2 mm short of working length was equal to 0.4 mm in three groups. Consequently, the results in each group were comparable.

Studies indicate that NiTi instruments may be more susceptible to separation than SS files (Camps & Pertot 1995, Thompson & Dummer 2000). When used in a mechanical rotary motion, unpredictable separation can be a feature of NiTi rotary instruments. The reasons mainly were nonconstant speed of rotation, excessively high rotational speed, overuse of instruments and too much pressure (Barbakow & Lutz 1997). Another important determinant of instruments fracture may be the canal curvature. When the curvature is more pronounced, the cyclical fatigue that the instrument undergoes is greater, which could contribute to separation (Pruett *et al.* 1997, Martín *et al.* 2003). For manual NiTi instruments, because of their flexibility, there is a loss of tactile sensation as compared with the more rigid SS K-files. When they were used in narrow curved canals, the tips can bind and not move in the narrow portion of the canal, whilst the shaft and the coronal part of the file are still active according to the direction of the force exerted by the operator. Under these circumstances, fracture might occur. In the current study, the tip of a size 30 NiTiflex file was separated in the apical portion of a canal with 42.1° curvature, which was the largest curvature in the experiment, and these anatomical constraints may have contributed to the fracture.

The centering ratio can define the ability of instruments to remain centered in shaped canals. According to the formula, the centering ratio approaches zero as X1 and X2 become closer. The lower the score, the better the instruments centered in the canal. In the current investigation, the results of the centering ratio in three groups at apical levels indicated that the ability of instruments to remain centered in prepared canals was significantly better in the GT and NT groups than in SS group. Corresponding to this, the distance of transportation with NiTi instrumentation was less than that with SS preparation. These findings confirmed the results previously reported for GT rotary files and other NiTi manual or rotary files in simulated resin canals or in extracted teeth (Glosson *et al.* 1995, Gluskin *et al.* 2001, Park 2001, Versümer *et al.* 2002). Studies also confirmed that apical transportation often occurred in curved canals prepared with some SS files, but NiTi instruments transport canals less and maintain the curvature (Royal

& Donnelly 1995, Portenier *et al.* 1998). In the present study, for GT and NiTiflex files, the flexibility of nickel–titanium and the blunt transition angle in the tip that allows the instrument to plane the canal walls rather than engaging and screwing into them, combined with balanced force technique, may contribute to the cutting of dentine evenly along the canal wall.

The difference in cross-sectional area of canals between pre- and postinstrumentation can be used to score the amount of dentine removed. It varies amongst different instruments and techniques. Previous studies showed that the amount of dentine removed and the distance of center transportation in curved canals prepared by SS Flexofiles were more than those in canals prepared by NiTi instruments (Portenier *et al.* 1998, Gluskin *et al.* 2001). Because of the high flexibility of nickel–titanium alloy, there is less straightening tendency in curved canals and minimal indiscriminate removal of dentine during instrumentation. For standard K-files, because of the inherent stiffness of stainless steel, there is a tendency for them to straighten the curved portion of the canal, and consequently this may result in more uneven and excessive dentine removal. Some researchers suggested that the reason NiTi instruments cause less transportation than SS K-files might not be the increased flexibility of NiTi instruments, but rather their decreased cutting ability (Gambill *et al.* 1996). The amount of dentine removed was associated with canal transportation. In general, the more the transportation, the more is the dentine removed. It has been confirmed that the centering ratio and the dentine removed in canals prepared with NiTi rotary and hand files were less than those in canals instrumented with SS K-Flex files (Glosson *et al.* 1995). In agreement with this view, the results at the apical level in the present study showed that in the group with high centering ratio and more transportation, more dentine removal was evident.

Conclusions

Under the conditions of this study, GT hand and NiTiflex files produced less transportation and remained more centered at apical third of the canals, compared with SS K-type files, when used in curved canals.

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